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QUALITY CONCRETE ON THE FARM

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(Replaces OMAFRA Factsheet, *Quality Concrete on the Farm*, Order No. 04-021)

Concrete is a material used on almost every farm because of its strength, form flexibility, and characteristics beneficial to environmentally sound practices. Processing and value-added facilities such as composting operations, biogas generation and anaerobic digestion facilities are using concrete as an integral part of their operations as well. Quality concrete provides:

- long service life
- lower annual maintenance costs
- fire resistance
- reduced bacterial growth
- easy to clean surface
- increased durability of surfaces that are resistant to cracking, abrasion, scaling, acids and other harsh environments
- environmental compliance

The quality of concrete is affected by a number of factors. This Factsheet describes the components of concrete, explains how it should be handled after mixing, and sets out what specifications are required for some agricultural projects.

WHAT IS CONCRETE?

Concrete is a mixture of Portland cement, water, fine aggregate (sand) and coarse aggregate (stone). Depending on a structure's requirements, these components are mixed in specific ratios to achieve the desired quality and design specifications.

When mixed, the water and cement form a paste, which coats the gravel and sand and bonds them together. Through a chemical process called "hydration", the cement reacts with the water to form gels, which grow to fill the spaces between the particles of the mix. In this way the concrete hardens into a rigid mass.

Increasing the strength of concrete makes it denser, more watertight and corrosion resistant. Changing the ratios of the four main components as well as using additives such as air-entraining, bonding and foaming agents, silica fume and fly ash will vary the characteristics of concrete.

Three main items affect the qualities of concrete:

- water/cementing materials ratio
- placement procedures
- curing

Most farm applications require concrete to be strong, dense, watertight and resistant to environmental exposure, i.e., freeze-thaw action. Storage structures, barn floors and feeding bunks need to be resistant to severe abrasion and chemical action. *Figure 1* shows a typical in-ground concrete structure used to store livestock manure.

FIGURE 1. High quality concrete is needed to construct barns and manure storage structures.

WATER/CEMENTING MATERIALS RATIO

The *water/cementing materials ratio* (W/CM) is the ratio, by weight, of the water to cement in a concrete mixture. Concrete for farm use needs a water/cementing material ratio of about 0.45. A water/cementing materials ratio of 0.45 means that for every 1 kg of cement in the mix, use 0.45 kg of water. The ratio should be slightly lower for severe exposures and can be slightly higher for mild exposures (see Table 1, *Exposure vs. Water/Cementing Materials Ratio and Minimum 28-Day Compressive*

Strength for exposure conditions). *Figure 2* demonstrates the effect of the water/cementing materials ratio on the compressive strength of concrete.

W/CM is an important factor in determining the strength and permeable properties of concrete.

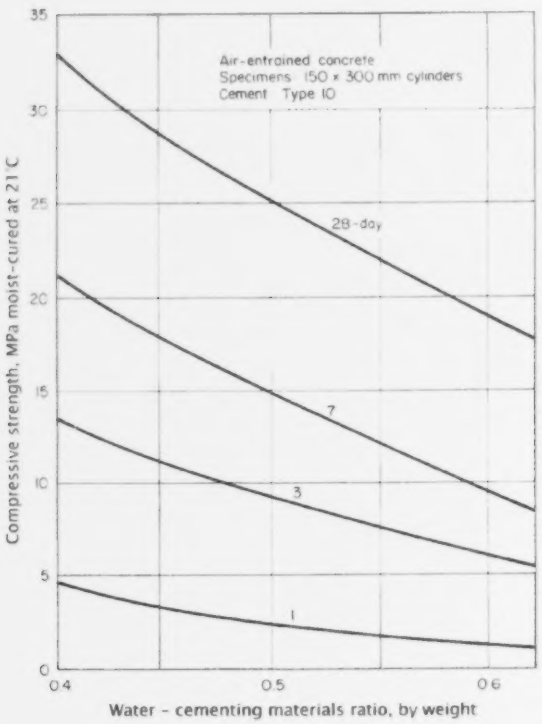

FIGURE 2. Compressive strength of concrete versus its Water/Cementing Materials Ratio.

The strength of concrete is measured in MegaPascals (MPa) of compressive strength. Applications on the farm vary from 15 MPa for below-grade footings to 35 MPa for severe applications like barn slats and reinforced beams.

If excess water is used in making the concrete, the resulting mixture has more space between the particles of the concrete mixture than can be filled by the cement gel. This results in a weaker, more porous and less durable concrete that may not be able to withstand the exposure for which it was designed. Adding as little as 2% extra water to a concrete mixture can reduce strength by 15%. Since farm concrete is usually subjected to severe exposure conditions, it needs to be of the highest quality possible.

TABLE 1. Exposure vs. Water/Cementing Materials Ratio and Minimum 28-Day Compressive Strength

Class of Concrete	Use	Maximum Water/ Cementing Material Ratio	Minimum 28-Day Compressive Strength, MPa
C-1	Severe exposure (silos, floor slats, manure tanks)	0.40	35
C-2	Normal exposure (barnyards, floors, walls, foundations, beams)	0.45	32
N	Mild exposure (footings) Non-reinforced Not exposed to freeze-thaw action	0.55	25

Note: All concrete should be air-entrained from 4%–8% of the concrete volume. Refer to CSA A23.1 Table 10.
Also see: Canadian Farm Builders Association – Guidelines for Concrete Specifications

PLACEMENT PROCEDURES FOR CONCRETE

Concrete should be "placed" and not "poured". Do not expect concrete to flow around form-work or over the ground. Place it within 1 m of its final position in the work. By doing this, separation of the paste from the aggregates is less likely.

Concrete placed in forms should be puddled or vibrated to achieve a dense product with minimum permeability that is free of air pockets. This procedure increases the strength and durability of the concrete, and allows excellent bonding to reinforced steel, joints and water stops.

Concrete placed in slabs requires leveling, floating and texturing as part of the placement process. If concrete can be placed, consolidated and finished without undue effort, it is said to be "workable". The workability of concrete can be increased by the addition of water, but this is not a desirable method unless the cement content is also increased to maintain the correct water/cementing material ratio. Instead, chemical admixtures can be mixed in to increase the workability without the use of water.

Concrete Additives

Admixtures include water reducers, superplasticizers and air-entrainers. Various admixtures affect workability, bonding, damp-proofing, permeability, grouting, gas-forming and pumping characteristics of concrete. To achieve concrete that meets or exceeds required code specification, follow proper mixing, placement and curing procedures without resorting to admixtures except air-entraining agents that are required for most farm applications. However, there are situations where the use of admixtures can:

- reduce costs of concrete projects
- achieve certain characteristics in concrete that cannot be obtained by other procedures
- maintain the quality during mixing, transportation, placing and curing of concrete, especially in adverse weather conditions
- contend with unexpected emergencies during all phases of concrete operations

Use the American Society for Testing and Materials (ASTM) standards when adding any admixture to concrete. The Canadian Standards Association (CSA) cites these standards in *A23.1 Concrete Materials and Methods of Concrete Construction* with respect to admixtures.

CURING

Proper curing of concrete has a very important influence on the final properties of the concrete. Curing is the process of maintaining the temperature and humidity conditions so that the cement hydration reaction can take place. Water must be **continually** available to the cement particles for hydration to continue. This continuing hydration will cause the concrete to become stronger, less porous and more durable. When moisture is no longer available, **hydration stops.**

Figure 3 shows the relative strengths of identical concrete cured for different periods of time. Concrete that has moist-cured for seven days has reached 75% of its rated strength and achieves 100% strength by the end of 180 days. By comparison, concrete cured for three days attains only 80% strength and uncured concrete, only 55% of its rated strength.

To maintain moisture, cover with plastic or apply spray-on curing compounds. These vapour barriers retain the water in the concrete by preventing evaporation. On level surfaces, add water by sprinkling or ponding, or by adding coverings such as waterproof films, damp sand, wet burlap or straw. On formed concrete, leaving the forms on helps contain moisture in the concrete.

To properly cure concrete, you must also control the temperature. The optimum temperature is 15°C (60°F) with the upper limit 32°C (90°F) and the lower limit 4°C (40°F). At high temperatures, apply cool water to keep the concrete cool. In cold weather, keep the concrete warm by using insulation, heated forms or heated enclosures. The setting of concrete generates heat that can be used if it is held in by insulation.

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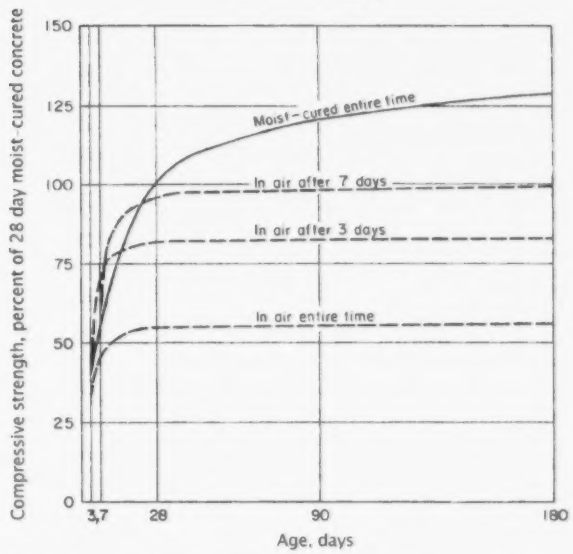

FIGURE 3. Proper curing results in an increase in concrete strength.

Fresh concrete must be protected from freezing because expanding ice crystals cause surface damage, cracking, increased permeability, heaving and structural faults. Protecting the concrete for at least three days at a temperature of 10°C or above allows the concrete to gain sufficient strength to withstand freeze-thaw cycles.

ADDING STRENGTH TO CONCRETE

To achieve early strength, add extra cement to the mixture. For farm-mixed concrete, increase the amount of cement as shown in Table 2, *Proportions by Mass to Make 1/10 cubic metre of Concrete for Small Jobs.* Curing is also very important when using a high-strength concrete at an earlier age. The length of time the concrete must be protected against freezing can be reduced from three days to one day, when high-early-strength concrete and good curing procedures are used.

TABLE 2. Proportions by Mass to Make 1/10 cubic metre of Concrete for Small Jobs[1]

	Air-entrained concrete			
Maximum size of coarse aggregate (mm)	**Cement (kg)**	**Wet, fine aggregate (kg)**	**Wet, coarse aggregate (kg)[2]**	**Water (kg)**
10	46	85	74	16
14	43	74	88	16
20	40	67	104	16
40	37	61	120	14

1. This mix is to be used in situations where structural capability is not critical.
2. If crushed stone is used, decrease coarse aggregate by 5 kg and increase fine aggregate by 5 kg.

The most common cause of poor quality concrete in farm projects is improperly cured concrete. To meet concrete's design strength, CSA A23.1 asserts that the normal curing period for concrete must be a minimum of three days at a minimum temperature of 10°C or when 40% of the 28-day strength (MPa) is achieved. For conditions of moderate to severe exposure to freeze-thaw or high sulphates, a curing period of 7 days or until 70% of the specified 28-day strength (MPa) is required.

ON-SITE MIXING

Use Table 3, *Proportions by Volume of Concrete for Small Jobs*, as a guide for mixing concrete for farm use. The water content may vary slightly from that suggested in the table, depending on the moisture content of the sand. After a rain, the water requirement will not be as great if the sand had been sitting through a period of hot, dry weather.

TABLE 3. Proportions by Volume of Concrete for Small Jobs[1]

Maximum size of coarse aggregate (mm)	Air-entrained concrete			
	Cement	Wet, fine aggregate	Wet, coarse aggregate	Water
10	1	2¼	1½	½
14	1	2¼	2	½
20	1	2¼	2½	½
40	1	2¼	3	½

[1] The combined volume is approximately two-thirds of the sum of the original bulk volumes. This mix is to be used in situations where structural capability is not critical.

AIR-ENTRAINMENT OF CONCRETE

All concrete on the farm should be air-entrained. Ordinary concrete contains about 2% entrapped air, but in large voids. Adding an air-entraining admixture results in millions of tiny air bubbles being produced in the concrete.

Increasing the air content up to a maximum of 8%:

- increases workability
- decreases permeability
- decreases freeze thaw damage
- reduces segregation

The tiny bubbles of entrained air act as a lubricant between aggregate particles, causing them to slide over one another easily. These tiny bubbles eliminate the large voids that allow water to penetrate and expand during freezing. This water is the cause of freeze-thaw damage in non air-entrained concrete. Since the entrained air increases workability, the water/cementing materials ratio can be reduced, thus increasing the strength, durability and wear resistance of the concrete. Air-entrainment is required by NSTS-04 Concrete, Steel or Equivalent Storage Facilities Protocol and Nutrient Management Act, Regulation 267/03 as amended for agricultural projects.

REGULATION AND SPECIFICATIONS FOR ON-FARM PROJECTS

The Canadian Farm Builders Association (CFBA) has released new concrete guidelines to address public concerns about the environmental integrity of agriculture buildings and manure storage structures. With input from consulting engineers, OMAFRA, the Ready Mixed Concrete Association of Ontario, contractors and building officials, guidelines have been developed to ensure all new construction projects meet the recent changes to Canadian Standards Association (CSA) A23.1, the Ontario Building Code and the National Farm Building Code of Canada (NFBC).

In particular, operators who mix their own concrete for farm projects need to be familiar with the various regulations, building codes and standards. Before mixing concrete, familiarize yourself with these requirements, including:

- CSA A23.1 *Concrete Materials and Methods of Concrete Construction* (Canadian Standards Associations)
- CSA A23.3 *Design of Concrete Structures*
- Ontario Building Code
- National Farm Building Code of Canada
- The O. Reg. 267/03 as amended and associated protocols made under the Nutrient Management Act, 2002 (NMA)

Concrete requirements are stated in Part VIII, Siting and Construction Standards of the NMA Regulation 267/03 as amended. Concrete quality is further described by established standards regarding concrete materials, properties, air-entrainment, admixtures, sulphate resistance and concrete covers, including specifications provided by CSA A 23.1 and A23.3.

READY-MIXED CONCRETE

Order ready-mixed concrete according to its final use. For example, use higher strength in high wear areas. For **flat** work, use 40 mm (1½ in.) maximum size aggregate and 50–100 mm (2–4 in.) slump. For **formed** work, use 20 mm (3/4 in.) maximum size aggregate and a 75–125 mm (3–5 in.) slump. Slump is a concrete specification that defines the workability of a concrete mix. The higher the slump, the more fluid the mixture.

In addition to the above specifications, all concrete on the farm should be air-entrained. The presence of tiny air

bubbles throughout the concrete greatly decreases the damage from frost and acids. Specify 5%–8 % when using 20 mm (3/4 in.) aggregate. **Do not add extra water**. The proper amount of water has been added to the mix at the plant and extra water will seriously affect the strength, durability, and water tightness of the finished concrete throughout its lifetime.

The advantages of using ready-mixed concrete supplied by a Ready Mixed Concrete Association of Ontario (RMCAO) certified concrete facility include:

- concrete meets W/CM ratio specifications and CSA requirements
- raw materials used to produce concrete are properly tested and certified prior to use
- ongoing quality and product testing to ensure concrete meets the minimum standards and
- audits and certification of member facilities

Ready-mixed concrete can be produced as a High Performance Concrete (HPC) when applications require improved durability, strength and impermeability. HPC has a maximum W/CM ratio of less than 0.36 and the minimum 28-day strength (MPa) designed by an engineer. Examples of HPC recommended applications include reinforced beams, slabs and columns over manure pits and silos, and floor slats as well as applications with high chemical exposures.

SUMMARY

Concrete is used on almost every farm building project. Be sure to follow the guidelines outlined in this Factsheet and adhere to all applicable codes and regulations. In doing so, you will produce concrete structures with the needed strength, durability and integrity.

References and Sources

- Ontario Regulation 267/03 as amended, made under the Nutrient Management Act, 2002
- CSA A23.1 *Concrete Materials and Methods of Concrete Construction*
- CSA A23.3 *Design of Concrete Structures*
- Ontario Building Code (OBC)
- National Farm Building Code of Canada (NFBCC)
- *Specifying Concrete for Agricultural Applications* M-9012, Canada Plan Service
- ASTM C494 *Specifications for Chemical Admixtures for Concrete*
- *Concrete Thinking in Agriculture Solutions: Concrete Manure Storage Structures, Specifications and Standards in Canada.* Cement Association of Canada, Dennis Darby, 2003
- *Guidelines for Concrete Specifications,* Canadian Farm Builders Association (CFBA)

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FOR YOUR NOTES

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Do you know about Ontario's new Nutrient Management Act?

The provincial Nutrient Management Act (NMA) and the Regulation 267/03, as amended, regulates the storage, handling and application of nutrients that could be applied to agricultural crop land. The objective is to protect Ontario's surface and groundwater resources.

Please consult the regulation and protocols for the specific legal details. This Factsheet is not meant to provide legal advice. Consult your lawyer if you have questions about your legal obligations.

For more information on the NMA call the Nutrient Management Information Line at 1-866-242-4460, e-mail *nman@omafra.gov.on.ca* or visit www.omafra.gov.on.ca.

Factsheets are continually being updated so please ensure that you have the most recent version.

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